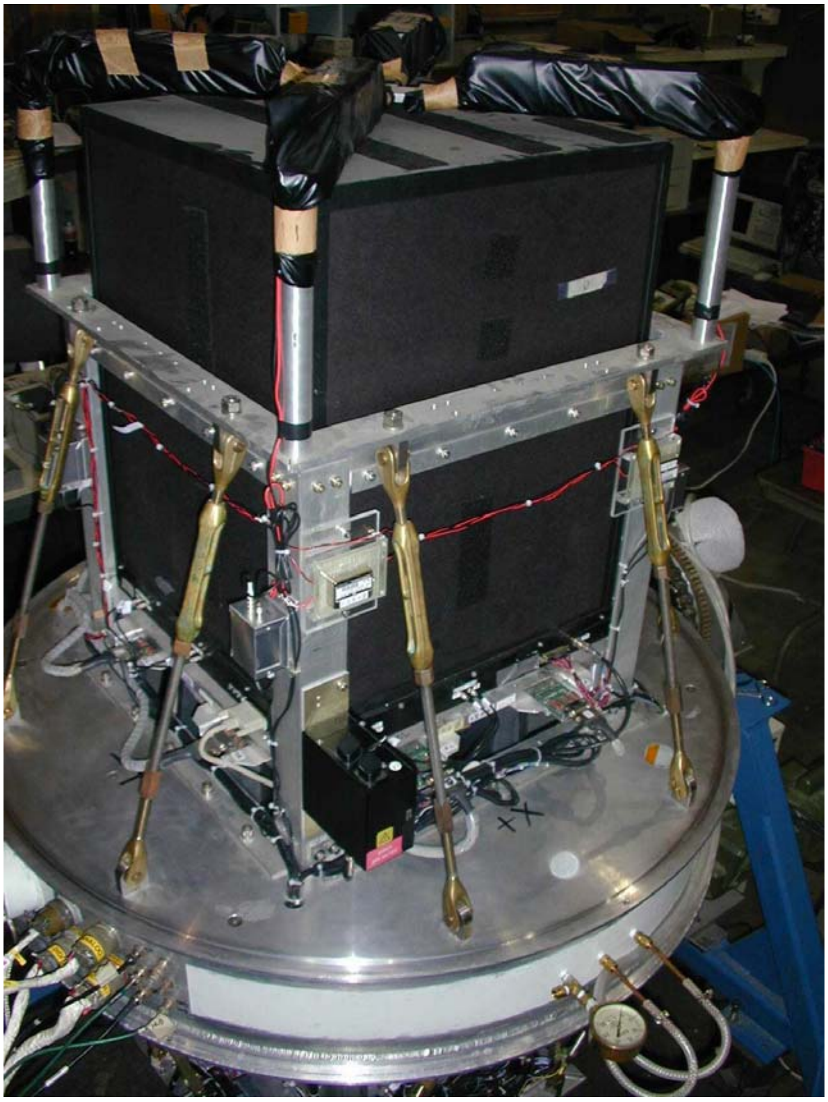
Gamma Ray Large Area Space Telescope (GLAST)
Large Area Telescope (LAT)
Balloon Flight Engineering Model (BFEM)

Pre-ship Review
Monday, July 16, 2001



Background - What and Why

The BFEM is a functional equivalent of one of the 16 LAT towers - the detectors (plastic scintillator anticoincidence, silicon strip tracker, and CsI calorimeter) are basically the same as the planned flight unit, although the electronics and readout are not the same as the flight design.

The balloon flight, which was strongly encouraged by the GLAST Announcement of Opportunity, will be the first time that a high-energy gamma-ray telescope has obtained an unbiased sample of all the types of events that could trigger a pair production type of telescope in a space-like environment.

The goals of the balloon flight are modest:

1. Demonstrate that this instrument design can successfully collect data in a background that contains a mixture of many particle and photon types, omnidirectional, and arriving at random times.

2. Collect enough data to allow several types of analysis:
    a. Comparison of trigger rates with expected particle fluxes
    b. Extraction of enough gamma-ray data to compare with previous measurements of the atmospheric background
    c. Comparison of results for events tagged by active external targets with those expected from simulations.

A few hours of live time at float altitude will be adequate to meet these goals. The NSBF request is for 8 hours float, 5 hours minimum.

Web sites with BFEM information:

http://balloon.stanford.edu/ -- The primary BFEM documentation

http://lheawww.gsfc.nasa.gov/users/djt/BALLOON/ -- An informal collection of information and pictures

This Review

This review is being held before shipment of the BFEM to the National Scientific Balloon Facility in Palestine, Texas, for its flight.

The principal focus of this review:

WHAT CAN GO WRONG AND WHAT HAVE WE DONE ABOUT IT

Topics - Potential Problems:

1. Detector problem
2. Data acquisition problem
3. Data storage problem
4. Thermal problem
5. Pressure vessel leak
6. Balloon failure
7. EMI/RFI
8. Operator Error
9. Software problem

Detector Problems?

The detectors are the same ones used for the 1999 beam test at SLAC.

They have all worked solidly during the testing, coming on in a working state every time they have been powered up.

The one known limitation is temperature - the Si strip tracker becomes noisy at temperatures above 30 C. The mitigation is to start the BFEM cold at launch and rely on the thermal design to keep the temperature low enough through the flight. At one cold start, one set of ACD signals disappeared. This is being investigated. See the section on thermal design.

Data Acquisition Problems?

Several problems have been seen with data acquisition, related to the tracker:

1. Events with many tracker hits can occasionally produce large dead times. Calculations show that the rate of these is small enough that they will have little impact on the total dead time. The BFEM has been shown to be capable of operating even when the trigger rate is artificially raised to the saturation level (about 6 KHz, when the expected rate is 1 KHz at float).

2. The tracker buffer is eight deep. If the tracker becomes noisy, it becomes possible to have enough triggers to fill this buffer. A full buffer causes the data readout to stop. Three mitigations: a. Keep the tracker cool enough to minimize the noise (see thermal analysis); b. Mask known Si strips that are known to be noisy; c. Include an automatic reset in the readout software to catch such events. The loss of data with such a reset is minimal.

3. The readout occasionally obtains an incorrect byte count from the data, causing events to be incorrectly packaged in the data stream. This appears to be related to rare timing mismatches on the backplane of the data acquisition system. Mitigations: a. New code has been added to alter the timing slightly (not enough to impact the dead time). Tests show that this greatly reduces the incidence of byte count mismatches; b. Software includes a trap that detects mismatches and resets, again with minimal loss of data unless the rate becomes much higher than seen even with artificially high trigger rates.

We have seen autonomous re-boots of the Data Acquisition System (DAQ) computer on power-up or power-down of some other components. This suggests noise spikes coming from the power supply or ground loops in the system. Although such re-boots are a concern, we may be able to live with them, because we have no plans to turn systems on or off except right after launch. The re-boots were seen primarily during testing, when not all cables were attached in flight configuration (one extender card was in place). The concern is that there is a susceptibility to some sort of noise. During one five-hour thermal run while running at 1.3 KHz trigger rate, we saw two other DAQ reboots - one for an unknown cause and one due to a tracker FIFO problem. This rate seems tolerable.

Data Storage Problem?

Because a goal is to obtain a massive unbiased data set, the trigger rate is far higher than can be telemetered to the ground. A set of six SCSI disks, each with a 70 Gbyte capacity, is used onboard for data storage, with relatively small data sets (1 GB) cycled through the six disks.

We have had both disk and cable problems:

1. Running at high temperature, one of the disks failed to mount. We discovered that the air circulation around the disk electronics was poor. The disk crate was rebuilt to allow much better circulation, and the crate itself was moved closer to fans. A long thermal run confirmed that the disks are no longer overheating.

2. On two occasions, the system failed to recognize one of the disks. In each case, a SCSI connector was found to be making poor contact. All the SCSI connectors have been firmly attached and bonded into place.

Thermal Problem?

Thermal analysis for balloon instruments is always difficult. Here are the steps we have taken to minimize the uncertainty:

1. The instrument is enclosed in a pressure vessel with a sizeable number of fans for air circulation. The air will distribute the heat so as to minimize hot spots. The vessel has been flown on balloons before and is well insulated. All exposed surfaces will be painted white.

2. We contracted with New Mexico State University for a simple balloon thermal analysis. Their conclusion was that the instrument would warm up during a flight, but not at a high enough rate to be a problem during a short flight. Their report is at http://lheawww.gsfc.nasa.gov/users/djt/BALLOON/GlastThermalReport.PDF

3. We carried out thermal testing at SLAC by running the instrument with the pressure vessel closed, a worst case for heating, since no cooling was applied. The temperature rise was found to be faster than predicted by NMSU, a result attributed to the assumed thermal mass of the BFEM. Assuming a lower thermal mass reproduced the observed rate and allowed a recalibration of the NMSU analysis. The result, shown at http://www.slac.stanford.edu/~godfrey/Balloon_6-04-01.pdf indicates that we will still be safe during the flight IF we can start with the BFEM cool at launch. This test was repeated at Goddard, with the same conclusion. The tracker heating is the hardest problem, because the tracker is not well connected thermally to the rest of the instrument. It is possible that the tracker temperature may exceed the 30 C. specification before the end of an 8 hour flight (although we have demonstrated 5 hours performance on the ground with no cooling).

4. We installed a radiator at the bottom of the instrument inside the pressure vessel, just below a set of nine fans, connected to a water line that penetrates the vessel. By running chilled water through the radiator, we can maintain or even cool the instrument on the ground even when it is in full operation. By running the fans and chiller without the rest of the instrument, it is possible to cool the entire BFEM before launch. This has been demonstrated in ground testing. Note, however, that cooling represents a potential conflict with last-minute testing.

Pressure Vessel Leak?

The thermal control of the BFEM depends on maintaining enough air for circulation in the vessel. In addition, the HV for the phototubes is not potted, so a very low pressure would cause corona. Finally, the disk drives are not rated for operation above an equivalent altitude of 10,000 ft. (about 10 psi). For all these reasons, the integrity of the pressure vessel is vital.

The vessel has been flown twice before, and a test to a differential pressure of 1.5 atmospheres was performed at SLAC before the instrument was installed. The report is at
http://lheawww.gsfc.nasa.gov/users/djt/BALLOON/Pressure_test_results.pdf

A leak test performed at Goddard with 1.5 psi differential showed a leak rate of 1 psi in 10 hours in one test and about half that rate in a second test. Although this is a bit higher than we would like, it seems acceptable for a short flight like this one.

A similar leak test will be performed with 2 psi differential before launch.

Balloon Failure?

Although NSBF has an excellent record, the success rate for balloons is only about 90%. There is some chance the balloon will fail during ascent or will not be able to maintain float altitude.

Mitigations:

1. We have designed the BFEM to withstand the parachute shock and landing shock, if they are not too severe. There is some chance that some layers of the tracker will fail with a large impact (> 10 G). Re-designing the tracker to withstand higher shocks was not an option.

2. We will request a valve-down before termination, if possible, so as to reduced the parachute shock.

3. We will include ample crush pads to cushion the landing shock..

4. If the balloon cannot hold altitude, we may still be able to meet most of our goals, since we are relying on the atmosphere as our source rather than on cosmic sources.

EMI/RFI?

We do not have one of the NSBF transmitters to test the BFEM against radiated power. This is a test that will be performed at NSBF.

We appear to be safe against self-induced EMI under all operating conditions, based on ground test.

Mitigation is that we are running the BFEM completely enclosed in a metal vessel that should reduce any RFI.

Operator Error?

Although vigilance is an important element of avoiding operator error (we have adopted a two-person rule for any turn-on of the instrument), a number of steps have been taken to reduce the chance of problems.

1. The number of commands is very limited. The system is designed to turn on in a working configuration. Principal commands are, therefore, power on commands to each subsystem.

2. The command console is graphic, with telltales for each subsystem status.

3. All power off and critical reset commands require a confirmation before they are sent.

4. All major tests are run from procedures. In particular, the flight line procedure is written out in detail, including explicit GO/NO_GO criteria.

5. The event display and housekeeping displays are fairly straightforward. Critical parameters such as temperature are shown graphically.

Software Problems?

The GLAST BFEM uses two on-board computers, one for the data acquisition system and one for the balloon interface (data and command handling). Both use the vxWorks real-time operating system, which has been used for these detectors since the 1999 beam test.

Nevertheless, considerable software had to be developed for this balloon flight, and software testing is always tricky. Our efforts to mitigate problems include:

1. As noted in the data acquisition section, the software is designed to trap and recover from known data anomalies.

2. The computers boot from on-board ROM into a working configuration, so that we could recover from a lock-up by cycling the power.

3. We plan to have extended running in the final flight configuration to watch for problems with the software.

4. We did encounter an instance in which the on-board ROM code did not match the ground version of the same code. This was traced to a defective flash memory on the CPU board. We are in the process of switching to our spare CPU board, and we will investigate the possibility of replacing the memory to convert the original board into a spare.

GLAST Balloon Flight Engineering Model (BFEM)
Flight Line Procedure

Part One – testing using power supply, before balloon inflation.

Configuration: BFEM on launch vehicle. Power for instrument from bench power supply plugged into generator. Power for command box from battery. Data and commands going through CIP and transmitter/receiver. Water chiller in operation, powered by generator. Using walkie-talkies to communicate with ground station in integration building.

Preliminary – turn on power (instructions repeated in step 10)

Establish radio link.

1. Login to the glast00 machine with public account name "balloon". The password is "albedo+"

2. Login to the goose machine with public account name "balloon". The password is "albedo+"

3. If necessary, log into the CalGSE PC: user = glasttem; password = glast.tem

4. On Screen One, Terminal Window #0 (**goose**) –

   ```
   goose% term b

   Responds with "connected"    This boots VxWorks on the GSE
   ```

5. Terminal Window #1 (goose) –

   ```
   goose% cmx login
   goose% BIUCNSL /data/balloon/biu
   ```

   This will start the BIU GSE display.

6. On Screen Two, Terminal Window #2 (goose) –

   ```
   goose% cmx login
   goose% CMDCNSL /data/balloon/cmd
   ```

   This will start the flight command console.

7. The TRX machine is located in the bottom half of the goose ground station. Power on the TRX external SCSI disk and VME chassis. Terminal Window #0

will display the serial console for the TRX. It will show “checksum error” until power is turned on.

8. Terminal Window #0 (**glast00**) –

```
glast00:balloon> tip hardwire

Responds with “connected”    Starts system listening to BIU

                              serial line.
```

9. Terminal Window #1 (glast00) –

```
glast00:balloon> launch &        Brings up Tornado launcher
glast00:balloon> tip hardwirea

Responds with “connected”       Sets up to listen to the
                                   DAQ Serial line

If system complains, it may have been rebooted.  In this
case,

glast00:balloon> wtxregd &

Then repeat
glast00:balloon> launch &     Brings up Tornado
                              launcher window on glast00
glast00:balloon> tip hardwirea

Responds with “connected”     Sets up to listen to the DAQ
                              Serial line
```

10. Power on BFEM

Turn on main and command power supplies with 28 V. Set current limit on main supply to 14 A. Also make sure power to CIP simulator is on.

When ready, power on the BIU. From the command console send:

```
Power BIU On
```

Terminal Window #0 will display the serial console for the BIU. Watch for “Done executing startup script” Also expect green light on Signal and Lock on the GSE VME. Also expect to stop getting checksum error on serial console.

Expected total current 1.6 A.

Check system and BIU voltages and currents on BIU console page.

The XGT power supply also powers the computer cooling fans. Send the following command from the command console to power on the XGT:

```
Power XGT On
```

Total power should go to 2.9 A. XGT power also powers a number of temperatures that can be read on the BIU console page.

When ready, power on the DAQ. From the command console send:

```
Power DAQ On      There will be an auto-
                    boot here
```

Total power should go to 5.4 A. Check voltages, currents, and temperatures on the BIU console page.

Terminal Window #1 will display the console for the DAQ.

When the DAQ is booted,
launch the Tornado target server named “bfdaq”. Highlight its name in the left column. This will start the Tornado tools.

Start an instance of WindSh by clicking on the bottom left button on the Tornado screen.

11. Terminal Window #2 (glast00) –

```
glast00:balloon> cmx login
glast00:balloon> BCI_rx
```

This will start the DAQ command status display.

12. Terminal Window #3 (glast00) –

```
glast00:balloon> run_dataHub
```

This will start the data hub software which forwards the raw telemetry data to the subsystem GSE displays.
Ports:
9200 BIU housekeeping
9202 Event stream

9203 Housekeeping
9204 Rate counters
repeater   Sends data on to other machines

13. Terminal Window #4 (glast00) –

```
glast00:balloon> eventDisplay

Options:    eventDisplay unbiased             default
            eventDisplay calEnergy        CAL energy
req.
```

This starts the Matlab integrated event display software.

14. Power on the instrument subsystems and disks. From the command console, send the following commands:

```
Power SCSI On     powers on disks
Power ACD On
Power TKR On
Power CAL On
```

Total power should go to 11.8 A. Check additional voltages, currents, and temperatures on the BIU console and on the DAQ housekeeping display page (need to add notes from Lauben about displaying this).

15. In the WindSh window: (**must have subsystems on before doing this**)

```
> cd "~/scripts"      can confirm with > pwd
> < JFM_load
> < JFM_run
```

This will start the DAQ flight software. The DAQ housekeeping information should be visible in Terminal Window #1.

16. Enter the following commands at the Command Console:

```
TKR Config Load <0>
CAL Reset
ACD Reset
DAQ Trigger Disable <ACD>
DAQ Trigger Disable <CAL>
DAQ Trigger Enable <TKR>
```

```
DAQ Disk Mount
```

These commands place the subsystems in the default operating mode of tracker TIR trigger. Total power should go to 12.5 A.

17. To start acquisition, enter the following command from the Command Console:

```
DAQ Run Start
```

These commands place the subsystems in the default operating mode of tracker TIR trigger. Total power should go to 12.5 A.

18. To stop acquisition, enter the following command from the Command Console:

```
DAQ Run Stop
```

End of Basic Power-Up Process

Confirm Basic Operation
If commands have gone through and data are being received, the CIP is working.
Verify event data look reasonable.
Verify rates and housekeeping (voltages, currents, temperatures).
See Basic Functional Test for commands and sample data.

We need to reach this point quickly, in order to make a "go no-go" decision. Once the balloon is taken out of the box, it should be used (re-packed balloons have a higher failure rate).

Go No-Go Criteria

a. **24/26 tracker layers functioning**
b. **All ACD tiles functioning**
c. **All CAL layers functioning (not necessarily all logs)**
d. **Internal temperature 20 C. or below**
e. **3/4 XGTs working**

Power Down

Make sure DAQ Run Stop has been done

Power down subsystems – ACD, CAL, TKR, SCSI

Power down DAQ

Leave instrument running for a while with chiller and fans operating.

Power down XGT

Power down BIU

Turn off instrument power supply. Leave chiller working.

Leave computers configured for operation.

Part Two – battery operation, during filling of balloon, before launch.

Configuration: BFEM on launch vehicle. **Power for instrument from battery box**. Power for command box from battery. Data and commands going through CIP and transmitter/receiver. Water chiller in operation, powered by generator. Using walkie-talkies to communicate with ground station in integration building.

Establish radio link

Power up BIU
Power up XGT
Power up DAQ
Power up TKR
Power up ACD
Power up CAL
Power up SCSI

Verify acceptable event performance. Check housekeeping voltages, currents, and temperatures.

Once the filling of the balloon has started, only a complete failure of the instrument justifies stopping a launch. The balloon is commited.

Part Three – just before launch.

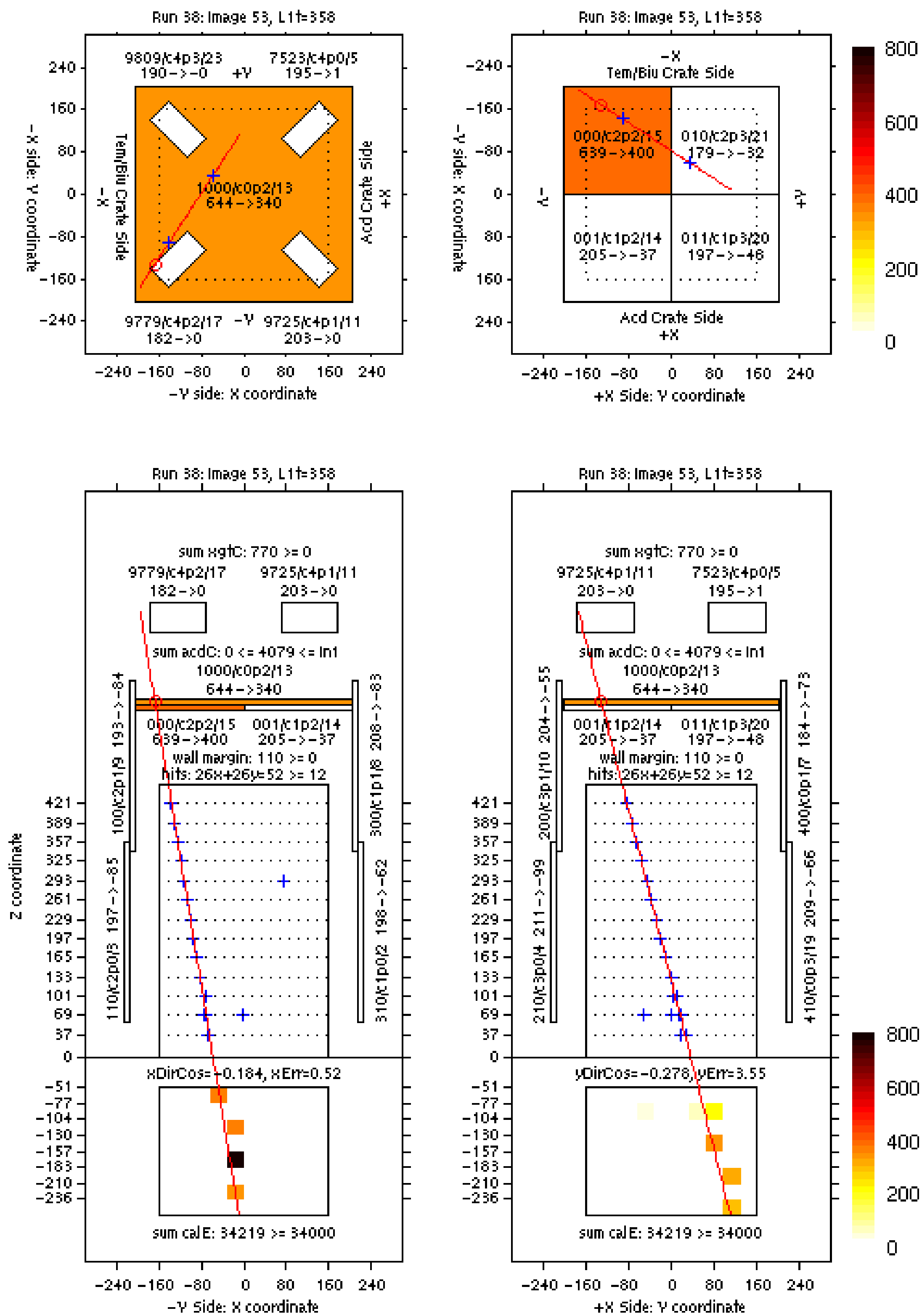
Critical Operations!

1. **Disconnect chiller lines and remove chiller**
2. **Power down SCSI**
3. **Clear away from the launch vehicle**

Part Four – just after launch.

1. **Power up SCSI**
2. **Reboot/reset systems as needed**
3. **Start data recording**
4. **Keep fingers crossed**

API



Run 38: Image 53, L1t=358
-Y side: X coordinate
-X side: Y coordinate
Tem/Biu Crate Side
Acd Crate Side
+X Side: Y coordinate
-Y side: X coordinate
Z coordinate
sum xgtC: 770 >= 0
sum acdC: 0 <= 4079 <= Inf
wall margin: 110 >= 0
hits: 26x+26y=52 >= 12
xDirCos=-0.184, xErr=0.52
yDirCos=-0.278, yErr=3.55
sum calE: 34219 >= 34000

Housekeeping Pages

Biu Housekeeping (VSAM)
09–Jul–2001 14:11:49 US/Pacific(wall clock)

ch	raw	calib		name	
0	0.16	8.01	A	sys28i	<10.5
1	3.79	27.74	V	sys28v	
2	4.50	29.35	V	cmd28v	
3	0.33	32.90	mA	cmd28i	
4	5.00	5.00	V	cmd5v	
5	0.29	0.29		spare0	
6	2.98	24.91	C	tkrBaseT	
7	2.97	24.07	C	topAirT	
8	2.46	4.92	V	daq5v	
9	−0.13	13.42	A	daq5i	
10	5.95	11.90	V	daq+12v	
11	0.00	72.16	mA	daq+12i	
12	−5.97	−11.95	V	daq−12v	
13	**0.01**	**384.47**	**mA**	**daq−12i**	**>380.0**
14	0.29	26.35	C	daqVicT	
15	3.22	48.52	C	daqCpuT	
16	2.53	5.06	V	biu5v	
17	−0.06	6.22	A	biu5i	
18	5.96	11.93	V	biu+12v	
19	0.01	226.75	mA	biu+12i	
20	−5.94	−11.89	V	biu−12v	
21	0.00	92.77	mA	biu−12i	
22	0.22	28.34	C	biuVicT	
23	2.97	23.77	C	botAirT	
24	0.32	0.63	V	diskA5v	<4.5
25	0.30	0.60	V	diskA12v	<11.0
26	0.29	18.37	C	diskAVicT	<20.0
27	−0.30	−0.60	V	diskB5v	<4.5
28	0.32	0.63	V	diskB12v	<11.0
29	0.32	46.89	C	diskBVicT	
30	2.97	23.86	C	bulkHdT	
31	2.95	22.11	C	radAirT	

Daq Housekeeping (VSAM) Calib UNVERIFIED!
09–Jul–2001 14:12:04 US/Pacific (wall clock)

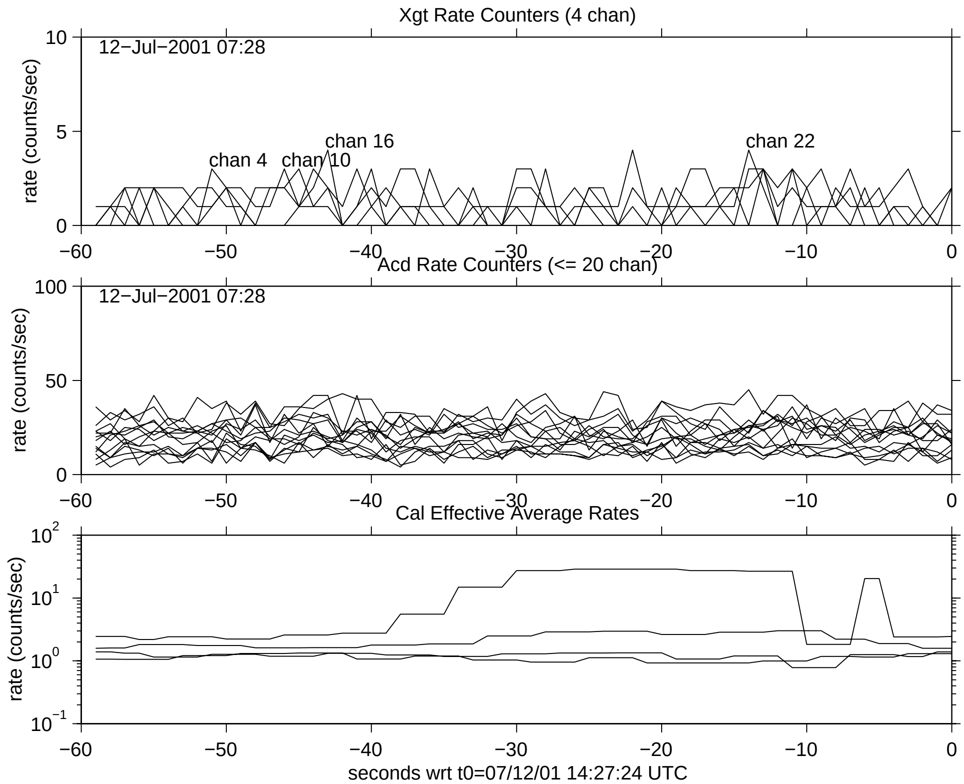
ch	raw	calib		name	
0	1.20	1.83	V	tkr2v	
1	2.41	1.44	A	tkr2i	
2	1.78	2.70	V	tkr3v	<2.8
3	3.52	2.11	A	tkr3i	
4	0.94	3.74	V	tkr5v	<4.8
5	0.56	0.34	A	tkr5i	
6	3.24	129.76	V	tkrHvV	
7	4.57	456.69	uA	tkrHvI	<480.0
8	0.30	29.93	C	tkrHvT	
9	3.42	5.18	V	cal5v	
10	1.03	0.62	A	cal5i	
11	0.30	29.82	C	calVicT	
12	0.01	10.03	C	calTopT	
13	2.48	4.97	V	acdDig5v	
14	−0.03	1.01	A	acdDig5i	
15	2.46	4.92	V	acdAna5v	
16	−0.04	1.30	A	acdAna5i	
17	7.98	31.91	V	acd28v	
18	−0.01	334.06	mA	acd28i	
19	0.30	39.45	T	acdVicT	
20	3.11	37.52	T	acdHvT	
21	0.27	0.54	V	xgt12v	<11.0
22	0.28	9.23	A	xgt12i	<10.0
23	0.30	29.93	C	xgtVicT	
24	1.99	497.89	V	xgtHv0	
25	1.88	469.10	V	xgtHv1	
26	1.94	485.66	V	xgtHv2	
27	1.98	495.79	V	xgtHv2	
28	0.33	−5.20	g	magRoll	
29	0.35	−5.15	g	magPitch	
30	−0.28	−0.01	Psi	ExtPr	<0.0
31	5.75	14.29	Psi	IntPr	

Sample Rate Counters - ACD

Acd/Xgt Rate Counters
09–Jul–2001 14:14:46 US/Pacific(wall)

chan 0:	0 Hz
chan 1:	22 Hz
chan 2:	16 Hz
chan 3:	32 Hz
chan 4:	1 Hz
chan 5:	0 Hz
chan 6:	27 Hz
chan 7:	34 Hz
chan 8:	28 Hz
chan 9:	24 Hz
chan 10:	1 Hz
chan 11:	0 Hz
chan 12:	29 Hz
chan 13:	15 Hz
chan 14:	20 Hz
chan 15:	0 Hz
chan 16:	2 Hz
chan 17:	0 Hz
chan 18:	25 Hz
chan 19:	7 Hz
chan 20:	12 Hz
chan 21:	0 Hz
chan 22:	0 Hz
chan 23:	0 Hz

Rates Plots



Plot of selected temperatures